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Age and Growth of Atlantic Croakers in the Northern Gulf of Mexico, Based on Otolith Sections

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Abstract

Otoliths from 1,291 Atlantic croakers *Micropogonias undulatus*, with total lengths from 113 mm to 417 mm, from the northern Gulf of Mexico were examined to determine age and growth. Marginal increment analysis was used to determine that otolith marks formed annually. Ages ranged from 0 to 8 years. No significant difference was found for length at age between males and females. The von Bertalanffy equation was $L_t = 419.2[1 - e^{-0.273(t+1.405)}]$, where L_t = total length (mm) and t = age (years). The length–weight relationship ($r = 0.99$) was $W = 5.302 \times 10^{-6} TL^{3.134}$ where W = weight (g) and TL = total length (mm).

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The Atlantic croaker *Micropogonias undulatus* ranges from the Gulf of Maine to Argentina along the coasts of the Atlantic Ocean and Gulf of Mexico (Chao and Musick 1977). Within the Gulf of Mexico it has been the most prevalent component of the groundfish fishery (Roithmayr 1964), and it is also an important sport fish (Gutherz et al. 1975; Nakamura 1981). Several authors have summarized and discussed the occurrence and life history of the species (Pearson 1929; Gunter 1945; White and Chittenden 1977; Nakamura 1981).

Ages of Atlantic croaker have been estimated from length-frequencies (Roithmayr 1964; Shealy et al. 1974), eye lens weight (Mericas 1977), and scales (White and Chittenden 1977). Length frequencies require subjective interpretation because Atlantic croakers have a prolonged spawning season and age groups overlap broadly in fish size (White and Chittenden 1977). Eye lens weights were no more accurate or precise for aging than length frequencies (Mericas 1977). Scales are difficult to interpret; they were reported to form two annular marks per year, except that no mark was formed during the first winter (White and Chittenden 1977). Other authors have found Atlantic croaker scales difficult to use for age determination (Suttkus 1955; Roithmayr 1964; Joseph 1972; Barger and Johnson 1980).

Although Atlantic croaker otoliths were found by Barger and Johnson (1980) to have more easily read marks than scales or vertebrae, they have not been used to determine age in years. The purpose of this study was to show that otoliths are useful structures for age determination of Atlantic croaker without many of the problems attributed to other methods of aging this species.

Methods

Between November 1980 and November 1981, monthly samples of Atlantic croakers totaling 1,291 specimens were obtained from catches of the RV *Oregon II* and commercial trawlers operating in the coastal waters off Mississippi, Louisiana, and Alabama. Total length (TL) to the nearest millimetre, weight to the nearest gram, and sex, when possible, were recorded. Otoliths (sagittae) were removed, wiped clean, and stored dry in glass vials. Because whole otoliths are thick and opaque they were mounted in Lakeside 70C[1] thermoplastic cement and cut transversely through the focus (Fig. 1) with a Buehler Isomet 11-1180 low-speed saw to remove thin sections about 0.18 mm thick. The thermoplastic cement then was dissolved with isopropyl alcohol, and sections were mounted on glass slides with Piccolyte cement.

Otolith sections were placed on a black background and opaque marks were examined in reflected light at 12× magnification. Measurements were taken from the focus to the distal edge of each mark and to the otolith edge (otolith radius, OR) along the sulcus acousticus radial

[1] Reference to trade names does not constitute an endorsement by the National Marine Fisheries Service.

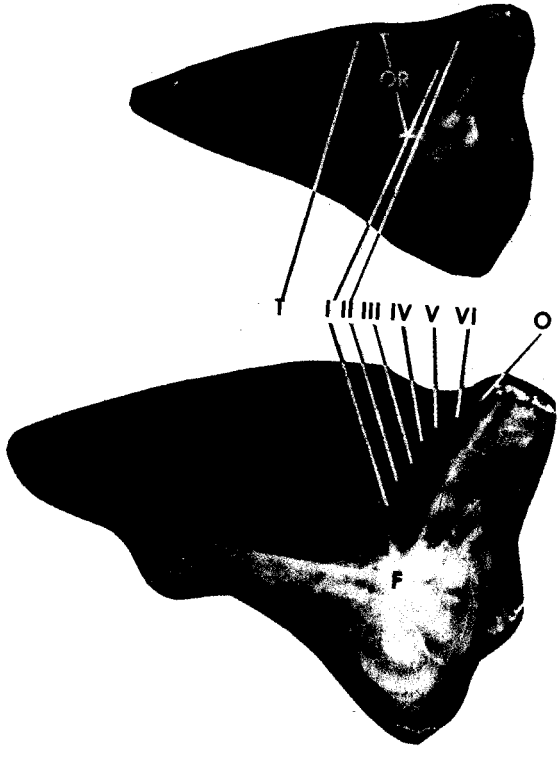

FIGURE 1.—*Cross-sections of Atlantic croaker otoliths viewed in reflected light. Annuli are marked for 2- and 6-year-old fish (captured in November and April with fork lengths = 229 and 366 mm). Otolith radius (OR) is from the focus (F) to the edge. S = sulcus acousticus radial, O = opaque margin, T = translucent margin.*

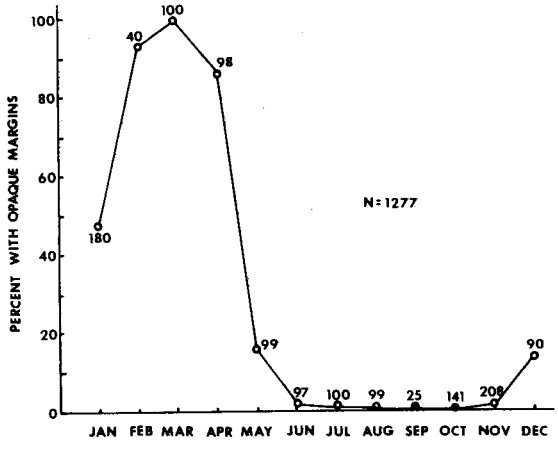

FIGURE 2.—*Percent of otoliths with opaque margins by month for Atlantic croaker. Numbers of otoliths are indicated next to points.*

most nearly perpendicular to the otolith edge (Fig. 1). All otoliths were examined by two readers to count the marks and to determine whether the edge was opaque or transparent. If there was disagreement in the number of marks the otolith was reread by both readers. If the readings still disagreed, the otolith was discarded.

The relationship between otolith radius and fish length was determined by least-squares regression with both linear and power fits. This relationship was used to back-calculate total length at earlier ages by methods adapted from Ricker (1975), Tesch (1971), and Everhart and Youngs (1981). Mean back-calculated lengths of males and females were then compared with the Student *t* test. A von Bertalanffy theoretical growth curve was fitted to mean back-calculated lengths with a modification of a computer program by Abramson (1971). The growth equation (von Bertalanffy 1938, 1957) is

TABLE 1.—*Mean back-calculated total length (mm) at age for Atlantic croakers from the northern Gulf of Mexico, sexes combined.*

Age group	*N*	Length at capture		Annulus							
		Range	Mean ± SD	1	2	3	4	5	6	7	8
I	320	113–363	219 ± 38	199							
II	70	194–407	269 ± 52	211	251						
III	23	203–375	304 ± 57	216	254	289					
IV	16	248–406	344 ± 50	215	261	300	330				
V	6	267–402	358 ± 48	219	262	393	321	346			
VI	3	366–398	385 ± 17	229	265	300	333	360	376		
VII	2	414–417	416 ± 2	227	281	309	345	366	390	406	
VIII	3	310–415	374 ± 56	220	260	299	315	331	349	362	369
Weighted mean				204	255	295	328	349	370	380	369
SD				31	42	45	41	36	34	45	54
Number	443			443	123	53	30	14	8	5	3
Annual increment				204	51	40	33	21	21	10	−11

TABLE 2.—*Total length (mm) of Atlantic croaker at age as reported by various authors for Gulf of Mexico populations.*

Study and method	Age (years)							
	1	2	3	4	5	6	7	8
Roithmayr (1964)								
Length frequency	120	170	200					
White and Chittenden (1977)								
Scale	160	275						
Rohr (1983)[a]								
Scale	179	263	330	385	430			
Barger (this study)								
Otolith	204	255	294	328	349	370	380[b]	369[b]
Herke (1971)								
Mark and recapture	245							

[a] B. Rohr, National Marine Fisheries Service, personal communication (no error estimate).
[b] The accuracy of this value is questionable due to small samples.

$$L_t = L_\infty[1 - e^{-K(t-t_0)}];$$

L_t = total length at age t;
L_∞ = maximum attainable length;
K = growth coefficient;
t_0 = time when length theoretically would be zero.

Length–weight analyses of males, females, and sexes combined followed Ricker's (1975) suggestions.

Results and Discussion

The two readers agreed on 99% (1,277 fish) of the otoliths. The remainder were either broken, badly eroded, or translucent, making accurate readings impossible.

Almost no otoliths had opaque margins from June to November, but they all did in March (Fig. 2). For otoliths with one mark, the mean distance from mark to otolith edge dropped sharply from 0.5 mm in January to 0.1 mm in February and 0.0 mm in March, where it remained until it increased gradually to 0.7 mm in September and October. There were not enough otoliths with more than one mark to demonstrate a complete annual cycle, but the ones available fit the same sequence. This pattern indicates that a single mark forms each year though it may occur any time from December to May for an individual fish.

The best relationship between total length of the fish and otolith radius was a power function: $TL = 112.89OR^{0.65}$ for which $r = 0.90$ ($N = 1,277$). This equation was used for back-calculated size at age.

Back-calculated size at age for males was generally smaller than females, but the differences were not statistically significant ($P = 0.01$). Therefore, sexes were combined for analysis.

Back-calculated fish lengths agreed reasonably with length at capture of corresponding age groups (Table 1). Differences are attributed to growth following mark formation. Atlantic croakers in the sample were as old as 8 years, but most were age 0 or 1. Because all samples were taken from available trawl catches, which by gear, location, and intent, target specific size groups, they did not necessarily reflect the age structure of the population. Length distributions at capture overlapped greatly among age groups (Table 1). Thus, as others had found (White and Chittenden 1977), fish length was a poor indication of age.

The back-calculated size of age-1 Atlantic croakers was larger than estimates from most other studies (Table 2). Some fish may have formed their first discernible otolith mark when they were older than 12 months, because the species spawns as early as September and as late as March in the Gulf of Mexico (White and Chittenden 1977). With this protracted spawning season it is reasonable that on many fish the first mark would not be formed at exactly 1 year. Fish that hatched early may have formed a mark within a few months of hatching, but it would have been close to the focus and probably too weak to be counted as an annular mark. In this study, at least 58% of the otoliths had marks that were too thin, or discontinuous, and too close to the focus to be counted as annuli. Under these conditions the next mark would have been formed in excess of 12 months after hatching and would be counted as an annular mark. In contrast, fish that hatched late could have formed the first

strong mark at a few months less than 1 year. All marks after the first mark would have been at annual intervals. The balance between these two cases determines the average growth before the first counted mark. The average growth period for age-1 fish in this study seems to be in excess of 12 months. The estimated sizes at older age from this study are intermediate between those of other studies (Table 2).

The von Bertalanffy growth equation was

$$L_t = 419.2[1 - e^{-0.273(t+1.405)}].$$

The theoretical maximum length (L_∞), 419 mm, was close to that of the largest specimen observed, 415 mm TL.

The relationship of weight (W, g) to total length (TL, mm) for Atlantic croakers (sexes pooled) from the Gulf of Mexico was described by the equation

$$W = 5.302 \times 10^{-6} TL^{3.134}; \; r = 0.99.$$

There was no significant difference in the regressions between sexes.

Otolith cross-sections are useful for determining age of Atlantic croakers in the northern Gulf of Mexico and should be so throughout the species' range. In future studies, attempts should be made to obtain representative samples of the entire population.

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